What is Claimed is:

1. A positioner system for controlling a pneumatic actuator coupled to a throttling element, the actuator having at least a first control chamber, the positioner system comprising:

an I/P converter delivering a pressure signal;

second stage pneumatics including a housing with an inlet port in fluid communication with a control fluid supply and a first outlet port in fluid communication with the first control chamber, and a control fluid valve assembly disposed in the housing and responsive to the pressure signal for controlling flow of control fluid from the inlet port to the first outlet port;

an inlet pressure sensor in fluid communication with the housing inlet port for measuring an inlet port pressure;

a first outlet pressure sensor in fluid communication with the first outlet port for measuring a first outlet port pressure;

a displacement sensor for detecting a control fluid valve assembly position; and

a diagnostics unit communicatively coupled to the inlet pressure sensor, first outlet pressure sensor, and displacement sensor, the diagnostics unit including a processor having a stored routine adapted to determine a first outlet port mass flow rate of control fluid based on the inlet port pressure, the first outlet port pressure, and a first outlet port area of restriction.

2. The positioner system of claim 1, in which the actuator further defines a second control chamber and the housing defines a second outlet port in fluid communication with the second control chamber, wherein the control fluid valve assembly further controls flow of control fluid from the inlet port to the second outlet port, and in which the positioner further comprises a second outlet pressure sensor in fluid communication with the second outlet port for measuring a second outlet port pressure, wherein the diagnostics unit is communicatively coupled to the second outlet pressure sensor and the routine is further adapted to determine a second outlet port mass flow rate of control fluid based on the inlet port pressure, the second outlet port pressure, and a second outlet port area of restriction.

3. The positioner system of claim 1, in which the control fluid valve assembly comprises a spool valve and the control fluid valve assembly position comprises a spool valve position.

4. The positioner system of claim 3, in which the routine is adapted to determine the first outlet port area of restriction based on the spool valve position.

5. The positioner system of claim 1, in which the control fluid valve assembly comprises a pneumatic relay having a beam and the control fluid valve assembly position comprises a beam position, wherein the routine is adapted to determine a first outlet port area of restriction based on the beam position.

6. The positioner system of claim 1, in which the routine determines the first outlet port mass flow rate dm/dt_1 in accordance with:

$$dm/dt_1 = K\ Y\ A_1\ g_c(2\rho(p_1-p_2))\ ½$$

where:

p_1 is the inlet port pressure;

p_2 is the outlet port pressure;

A_1 is the first outlet port area of restriction;

K is a discharge coefficient;

Y is an expansion factor;

g_c is a conversion constant; and

ρ = an upstream fluid density.

7. The positioner system of claim 6, in which the actuator further defines a second control chamber and the housing defines a second outlet port in fluid communication with the second control chamber, wherein the control fluid valve assembly further controls flow of control fluid from the inlet port to the second outlet port, and in which the positioner further comprises a second outlet pressure sensor in fluid communication with the second outlet port for measuring a second outlet port pressure, wherein the diagnostics unit is communicatively coupled to the second

outlet pressure sensor and the routine is adapted to determine a second outlet port mass flow rate of control fluid based on the inlet port pressure, the second outlet port pressure, and a second outlet port area of restriction.

8. The positioner system of claim 7, in which the routine determines the second outlet port flow rate dm/dt_2 in accordance with:

$$dm/dt_2 = K\ Y\ A_2\ g_c(2\rho(p_1-p_3))^{1/2}$$

where:

p_1 is the inlet port pressure;

p_3 is the second outlet port pressure;

A_2 is the second outlet port area of restriction;

K is a discharge coefficient;

Y is an expansion factor;

g_c is a conversion constant; and

ρ = an upstream fluid density.

9. The positioner system of claim 1, in which the control fluid comprises air, and in which the routine determines the first outlet port mass flow rate dm/dt_1 in accordance with:

$$dm/dt_1 = 0.048\ K\ Y\ A_1\ (p_1\ (p_1-p_2\ ))^{1/2}$$

where:

p_1 is the inlet port pressure;

p_2 is the outlet port pressure;

A_1 is the first outlet port area of restriction;

K is a discharge coefficient, and

Y is an expansion factor.

10. The positioner system of claim 1, in which the positioner comprises the diagnostics unit.

11. The positioner system of claim 1, in which a remote host comprises the diagnostics unit.

12. In a control loop for a control valve having a throttling element, the control loop including an actuator coupled to the throttling element and defining a first control chamber, and a positioner including second stage pneumatics having a housing defining an inlet port in fluid communication with a control fluid supply and a first outlet port in fluid communication with the first control chamber, a control fluid valve assembly disposed in the housing for controlling flow of control fluid from the inlet port to the first outlet port, a method for determining a first outlet port mass flow rate of control fluid comprising:

generating an inlet port pressure value by measuring fluid pressure at the housing inlet port;

generating a first outlet port pressure value by measuring fluid pressure at the housing first outlet port;

generating a control fluid valve assembly travel value by detecting a position of the control fluid valve assembly; and

calculating the first outlet port mass flow rate based on the inlet port pressure value, the first outlet port pressure value, and a first outlet port area of restriction.

13. The method of claim 12, in which the actuator further defines a second control chamber and the housing defines a second outlet port in fluid communication with the second control chamber, wherein the control fluid valve assembly further controls flow of control fluid from the inlet port to the second outlet port, the method further comprising:

generating a second outlet port pressure value by measuring fluid pressure at the housing second outlet port; and

calculating a second outlet port mass flow rate based on the inlet port pressure value, the second outlet port pressure value, and a second outlet port area of restriction.

14. The method of claim 13, in which the first and second outlet port mass flow rates are calculated using a mass flow rate equation.

15. A method for detecting faults in a pneumatic control loop for a control valve having a throttling element, the control loop including an actuator coupled to the throttling element and defining a first control chamber, a positioner including second stage pneumatics having a housing with an inlet port in fluid communication with a control fluid supply and a first outlet port in fluid communication with the first control chamber, a control fluid valve assembly disposed in the housing, an inlet pressure sensor in fluid communication with the inlet port, a first outlet pressure sensor in fluid communication with the first outlet port, and a displacement sensor for detecting a control fluid valve assembly position, the method comprising:

calculating a first mass flow rate of control fluid through the first outlet port using the inlet pressure sensor, first outlet pressure sensor, and displacement sensor to develop a first mass flow profile; and

generating a fault signal based on the first mass flow profile in accordance with a logic sub-routine.

16. The method of claim 15, in which the logic sub-routine generates a fault signal when the first mass flow profile exhibits a sustained increase.

17. The method of claim 15, in which the logic sub-routine generates a fault signal when the first mass flow profile exhibits a sustained decrease.

18. The method of claim 15, in which the logic sub-routine generates a fault signal when the first mass flow profile exhibits a sustained decrease while the displacement sensor indicates the control fluid valve assembly is off a null position.

19. The method of claim 15, in which the actuator further defines a second control chamber and the spool valve housing further defines a second outlet port in fluid communication with the second control chamber, the control loop further

including a second outlet pressure sensor, wherein the method further comprises calculating a second mass flow rate of control fluid through the second outlet port using the inlet pressure sensor, second outlet pressure sensor, and displacement sensor to develop a second mass flow profile, and wherein the logic sub-routine generates the fault signal based on at least the first and second mass flow profiles.

20. The method of claim 19, in which the logic sub-routine generates a first chamber leak fault signal when the first mass flow profile exhibits a sustained increase and the second mass flow profile is substantially constant.

21. The method of claim 19, in which the logic sub-routine generates a piston ring fault signal when one of the first and second mass flow profiles exhibits a sustained increase and a remaining one of the first and second mass flow profiles exhibits a sustained decrease.

22. The method of claim 19, further comprising calculating a crossover pressure by averaging pressure values from the first and second outlet pressure sensors, wherein the logic sub-routine further bases the fault signal on the crossover pressure.

23. The method of claim 22, in which the logic sub-routine generates a first chamber leak fault signal when the first mass flow profile exhibits a sustained increase, the second mass flow profile is near zero, and the crossover pressure is reduced.

24. The method of claim 22, in which the logic sub-routine generates a second chamber leak fault signal when the first and second mass flow profiles are near zero and the crossover pressure is reduced.

25. A control loop for positioning a throttling element of a pneumatically operated control valve, the control loop comprising:

an actuator for driving the throttling element, the actuator being disposed in an actuator housing defining at least a first control chamber;

a positioner including second stage pneumatics having a housing defining an inlet port in fluid communication with a control fluid supply and a first outlet port in fluid communication with the first control chamber, and a control fluid valve assembly disposed in the housing for controlling flow of control fluid from the inlet port to the first outlet port;

an inlet pressure sensor in fluid communication with the housing inlet port for measuring an inlet port pressure;

a first outlet pressure sensor in fluid communication with the first outlet port for measuring a first outlet port pressure;

a displacement sensor for determining a control fluid valve assembly position; and

a diagnostics unit communicatively coupled to the inlet pressure sensor, first outlet pressure sensor, and displacement sensor, the diagnostics unit including a processor having a stored routine adapted to determine a first outlet port mass flow rate of control fluid based on the inlet port pressure, the first outlet port pressure, and a first outlet port area of restriction to develop a first mass flow profile, and a logic sub-routine adapted to generate a fault signal in response to the mass flow rate profile.

26. The control loop of claim 25, in which the logic sub-routine generates a fault signal when the first mass flow profile exhibits a sustained increase.

27. The control loop of claim 25, in which the logic sub-routine generates a fault signal when the first mass flow profile exhibits a sustained decrease.

28. The control loop of claim 25, in which the logic sub-routine generates a fault signal when the first mass flow profile exhibits a sustained decrease while the displacement sensor indicates the control fluid valve assembly is off a null position.

29. The control loop of claim 25, in which the actuator further defines a second chamber and the housing further defines a second outlet port in fluid communication with the second chamber, wherein the control fluid valve assembly further controls flow of control fluid from the inlet port to the second outlet port, the control loop further including a second outlet pressure sensor communicatively coupled to the diagnostics unit, wherein the routine is further adapted to calculate a second mass flow rate of control fluid through the second outlet port based on the inlet port pressure, the second outlet port pressure, and a second outlet port area of restriction to develop a second mass flow profile, and wherein the logic sub-routine generates the fault signal based on at least the first and second mass flow profiles.

30. The control loop of claim 29, in which the logic sub-routine generates a first chamber leak fault signal when the first mass flow profile exhibits a sustained increase and the second mass flow profile is substantially constant.

31. The control loop of claim 29, in which the logic sub-routine generates a piston ring fault signal when one of the first and second mass flow profiles exhibits a sustained increase and a remaining one of the first and second mass flow profiles exhibits a sustained decrease.

32. The control loop of claim 29, in which the routine is further adapted to calculate a crossover pressure by averaging pressure values from the first and second outlet pressure sensors, wherein the logic sub-routine further bases the fault signal on the crossover pressure.

33. The control loop of claim 32, in which the logic sub-routine generates a first chamber leak fault signal when the first mass flow profile exhibits a sustained increase, the second mass flow profile is near zero, and the crossover pressure is reduced.

34. The control loop of claim 32, in which the logic sub-routine generates a second chamber leak fault signal when the first and second mass flow profiles are near zero and the crossover pressure is reduced.

35. A method for detecting faults in a control loop for a pneumatically operated control valve, the control loop including an actuator, second stage pneumatics having a control fluid valve assembly responsive to a pressure signal for controlling flow of control fluid to the actuator, an I/P converter adapted to receive an I/P drive signal and generating the pressure signal, and a processor for delivering the I/P drive signal to the I/P converter, the method comprising:

defining a normal range for a control parameter of the control loop;

triggering a fault signal for operation of the control parameter outside the normal range;

characterizing operating parameters of the control loop during the fault signal to derive a fault template;

comparing the fault template to sets of stored operating parameters associated with specific component failures; and

identifying at least one specific component failure having a set of stored operating parameters that matches the fault template.

36. The method of claim 35, in which the second stage pneumatics comprises a spool valve, and in which the control parameter comprises a spool valve position signal.

37. The method of claim 35, in which the second stage pneumatics comprises a pneumatic relay having a beam, and in which the control parameter comprises a beam position signal.

38. The method of claim 35, in which the control parameter comprises an I/P drive signal.

39. The method of claim 35, in which characterization of the operating parameters includes:

characterizing an I/P drive signal deviation as high or low;

characterizing an error signal as largely positive, null, or largely negative, wherein the error signal is equal to a reference signal minus an actuator travel signal;

characterizing an outlet port differential pressure as negative, nominal, or positive, wherein the outlet port differential pressure is equal to a first outlet port pressure minus a second outlet port pressure; and

characterizing a control fluid valve assembly position as largely positive, null, or largely negative.

40. The method of claim 39, in which characterization of the operating parameters further includes characterizing the reference signal after the I/P drive signal deviation has been characterized but before the error signal, outlet port differential pressure, and spool valve position have been characterized.

41. The method of claim 39, in which a fault template comprising a high I/P drive signal deviation, largely positive error signal, negative outlet port differential pressure, and largely negative control fluid valve assembly position is attributable to one of a group of component faults consisting of a jammed spool valve, an inlet O-ring failure, a diaphragm failure, and a blocked primary orifice.

42. The method of claim 39, in which a fault template comprising a high I/P drive signal deviation, largely positive error signal, nominal outlet port differential pressure, and largely positive control fluid valve assembly position is attributable to one of a group of component faults consisting of an external leak, a worn spool valve, and a low supply pressure.

43. The method of claim 39, in which a fault template comprising a high I/P drive signal deviation, largely positive error signal, nominal outlet port differential

pressure, and largely negative control fluid valve assembly position is attributable to a low supply pressure.

44. The method of claim 39, in which a fault template comprising a high I/P drive signal deviation, largely positive error signal, positive outlet port differential pressure, and largely positive control fluid valve assembly position is attributable to one of a group of component faults consisting of a throttling element stuck at low travel, a blocked air line, and an active interlock.

45. The method of claim 39, in which a fault template comprising a high I/P drive signal deviation, null error signal, nominal outlet port differential pressure, and null control fluid valve assembly position is attributable to one of a group of component faults consisting of a partially plugged primary orifice, grit in the armature, and a shift in I/P calibration.

46. The method of claim 39, in which a fault template comprising a low I/P drive signal deviation, largely negative error signal, positive outlet port differential pressure, and largely positive control fluid valve assembly position is attributable to one of a group of component faults consisting of a blocked I/P nozzle, a pressed I/P armature, a latched I/P, and a jammed spool valve.

47. The method of claim 39, in which a fault template comprising a low I/P drive signal deviation, largely negative error signal, negative outlet port differential pressure, and largely negative control fluid valve assembly position is attributable to one of a group of component faults consisting of a valve stuck in a high position and a blocked air line.

48. The method of claim 39, in which a fault template comprising a low I/P drive signal deviation, null error signal, nominal outlet port differential pressure, and null control fluid valve assembly position is attributable to one of a group of

component faults consisting of a shift in I/P calibration and a partially plugged I/P nozzle.

49. A control loop for positioning a throttling element of a pneumatically operated control valve, the control loop comprising:

an actuator for driving the throttling element, the actuator defining first and second control chambers;

second stage pneumatics having an inlet port in fluid communication with a control fluid supply, first and second outlet ports in fluid communication with the first and second actuator control chambers, respectively, and a control fluid valve assembly for controlling flow of control fluid from the inlet port to the first and second outlet ports;

an I/P converter having a pressure-responsive diaphragm engaging the control fluid valve assembly, the I/P converter further including an inlet in fluid communication with the control fluid supply and an outlet for directing control fluid to the diaphragm;

at least one sensor for detecting an operating parameter;

a processor communicatively coupled to the at least one sensor for providing a drive signal to the I/P converter; and

a diagnostics unit communicatively coupled to the processor, the diagnostics unit including a memory programmed to:

define a normal range for the operating parameter;

trigger a fault signal for operation of the control parameter outside of the normal range;

characterize operating parameters of the control loop during the fault signal to derive a fault template;

compare the fault template to sets of stored operating parameters associated with specific component failures; and

identify at least one specific potential component failure having a set of stored operating parameters corresponding to the fault template.

50. The control loop of claim 49, in which the control fluid valve assembly comprises a spool valve, and in which the control parameter comprises a spool valve position signal.

51. The control loop of claim 49, in which the control fluid valve assembly comprises a pneumatic relay having a beam, and in which the control parameter comprises a beam position signal.

52. The control loop of claim 49, in which the control parameter comprises an I/P drive signal.

53. The control loop of claim 49, in which the at least one sensor comprises an inlet port sensor in fluid communication with the second stage pneumatics inlet port, a first outlet port sensor in fluid communication with the second stage pneumatics first outlet port, a second outlet port sensor in fluid communication with the second stage pneumatics second outlet port, and a displacement sensor for determining a control fluid valve assembly position, and in which the memory is programmed to:

characterize an I/P drive signal deviation as high or low;

characterize an error signal as largely positive, null, or largely negative, wherein the error signal is equal to a reference signal minus an actuator travel signal;

characterize an outlet port differential pressure as negative, nominal, or positive, wherein the outlet port differential pressure is equal to a first outlet port pressure minus a second outlet port pressure; and

characterize the control fluid valve assembly position as largely positive, null, or largely negative.

54. The control loop of claim 53, in which the memory is further programmed to characterize the reference signal after the I/P drive signal deviation has been characterized but before the error signal, outlet port differential pressure, and spool valve position have been characterized.

55. A method for detecting faults in a control loop for a pneumatically operated control valve, the control loop including an actuator, a control fluid valve assembly adapted to receive a pressure signal and control flow of control fluid to the actuator, an I/P converter coupled to the control fluid valve assembly, and a processor for delivering an I/P drive signal to the I/P converter, the method comprising:

monitoring the I/P drive signal and at least one operating parameter of the control loop;

generating a fault signal based on the I/P drive signal and the at least one operating parameter in accordance with a logic sub-routine.

56. The method of claim 55, in which the at least one operating parameter comprises a control fluid valve assembly position.

57. The method of claim 56, in which the fault signal is generated when the I/P drive signal exhibits a sustained increase and the control fluid valve assembly position is at null.

58. The method of claim 57, in which the fault signal indicates a plugged primary orifice in the I/P converter.

59. The method of claim 57, in which the fault signal indicates a failure of an outlet O-ring in the I/P converter.

60. The method of claim 56, in which the fault signal is generated when the I/P drive signal exhibits a sustained decrease and the control fluid valve assembly position is positive.

61. The method of claim 60, in which the fault signal indicates a plugged nozzle in the I/P converter.

62. The method of claim 60, in which the control fluid valve assembly comprises a spool valve and the control fluid valve assembly position comprises a spool valve position.

63. The method of claim 60, in which the control fluid valve assembly comprises a pneumatic relay having a beam, and the control fluid valve assembly position comprises a beam position.

64. A positioner system for receiving a drive signal and controlling a pneumatic actuator coupled to a throttling element, the actuator having at least a first control chamber, the positioner system comprising:

an I/P converter adapted to receive the drive signal, the I/P converter generating a pressure signal based on the drive signal;

second stage pneumatics including a housing with an inlet port in fluid communication with a control fluid supply and a first outlet port in fluid communication with the first control chamber, and a control fluid valve assembly disposed in the housing and responsive to the pressure signal for controlling flow of control fluid from the inlet port to the first outlet port;

a displacement sensor for determining a control fluid valve assembly position; and

a diagnostics unit communicatively coupled to the displacement sensor and including a processor having a stored routine adapted to generate diagnostics information based on the control fluid valve assembly position.

65. The positioner system of claim 64, in which the control fluid valve assembly comprises a spool valve, and in which the control fluid valve assembly position comprises a spool valve position.

66. The positioner system of claim 64, in which the control fluid valve assembly comprises a pneumatic relay having a beam, and in which the control valve assembly position comprises a beam position.

67. The positioner system of claim 64, in which the stored routine compares the control fluid valve assembly position to the drive signal to generate the diagnostics information.

68. The positioner system of claim 64, in which the actuator further defines a second control chamber and the housing defines a second outlet port in fluid communication with the second control chamber, wherein the control fluid valve assembly further controls flow of control fluid from the inlet port to the second outlet port.

69. The positioner system of claim 64, in which the diagnostics information comprises actuator diagnostics information.

70. The positioner system of claim 64, in which the diagnostics information comprises I/P converter diagnostics information.